Advanced Photon Source

# APS Vision and New Initiatives

J. Murray Gibson

for 3-way meeting
06/02/03

# APS Today

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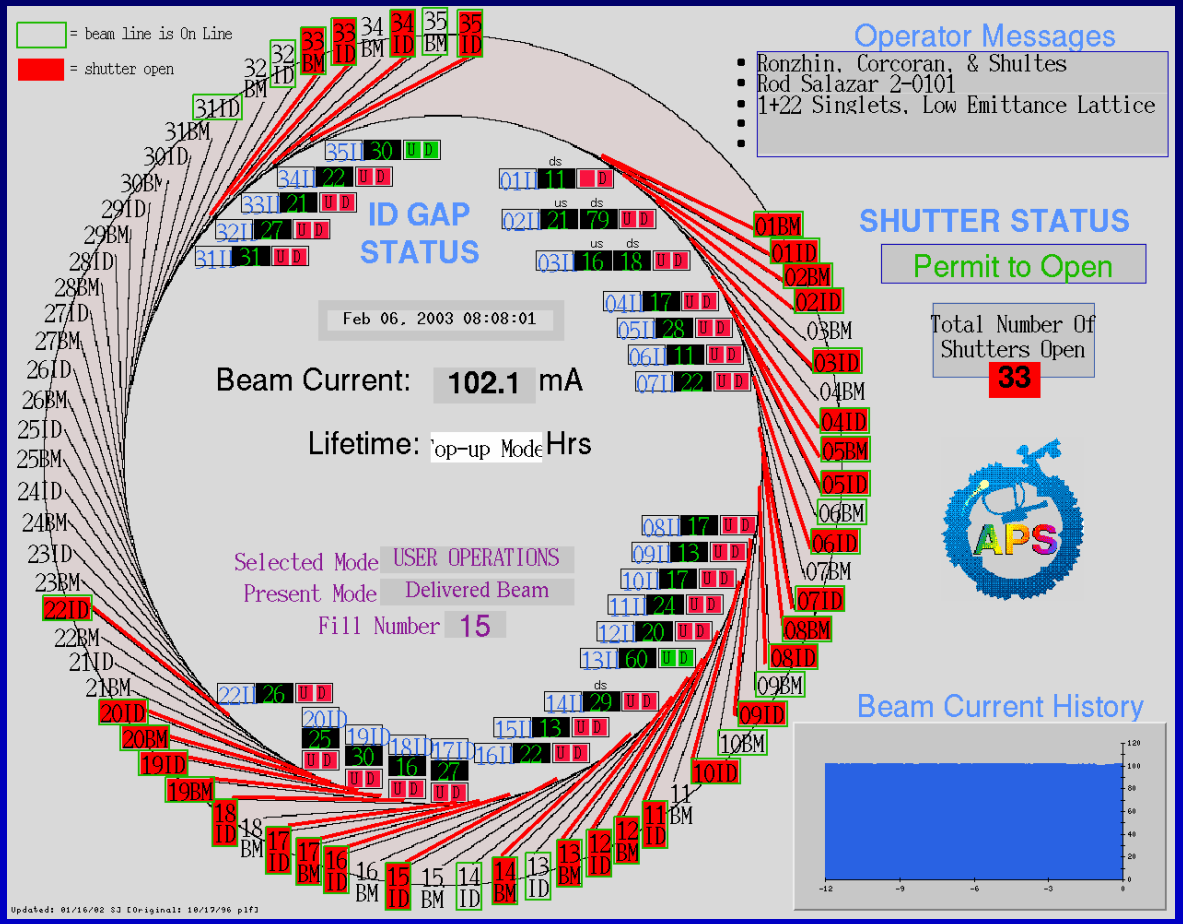


38 functioning beamports (25ID, 13BM)
68 total available

…only 4 ID beamports are not yet committed

# APS Users Today

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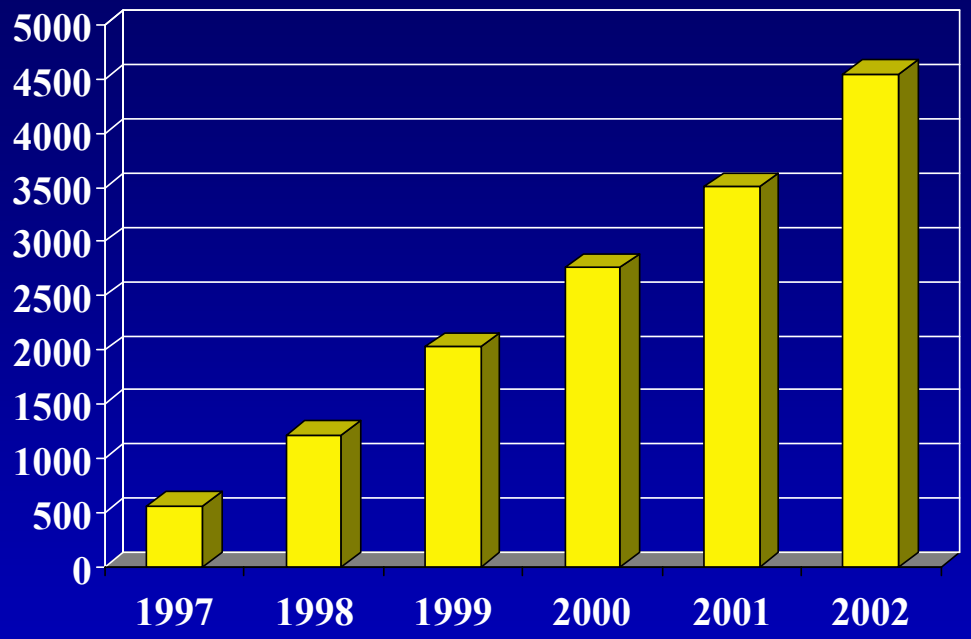
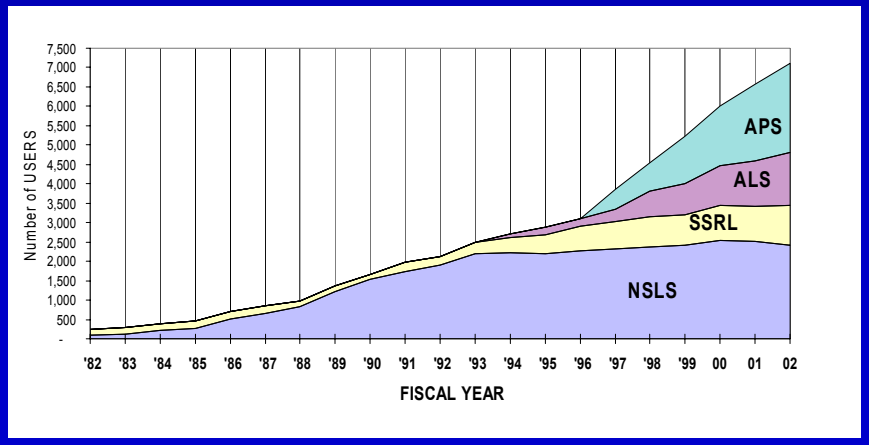
Badged Users




2400 unique users in 2002

# Demographics of APS Users (2002)

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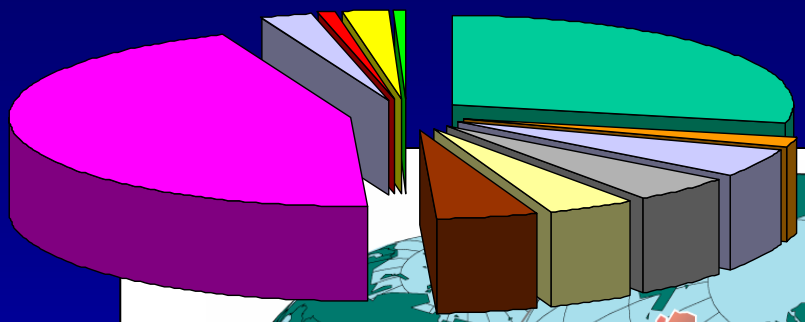


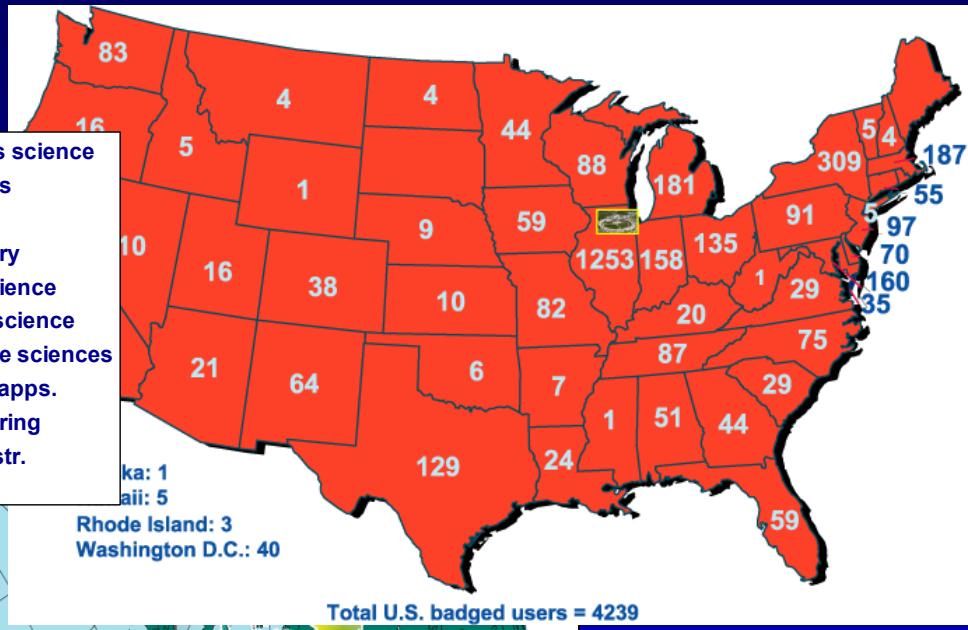


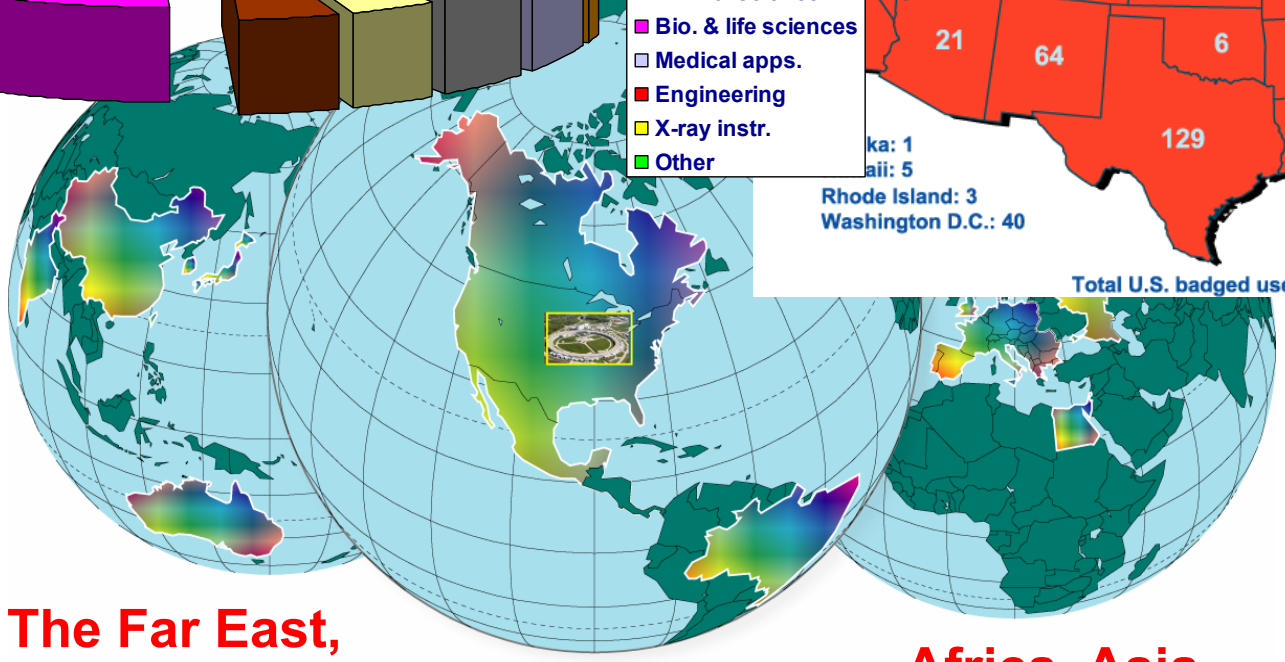

The Far East, South-East Asia, the Subcontinent, & the South Pacific: 186

The Americas: 4227

Africa, Asia, Europe, & the Middle East: 391

# Our first *centralized* general-user program

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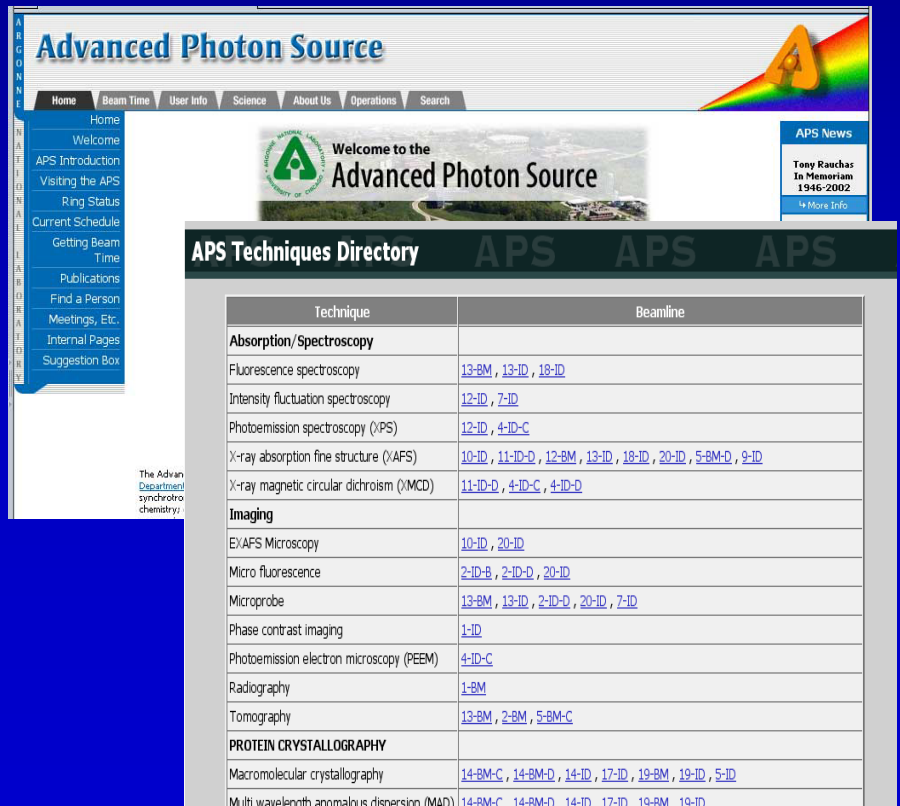
**Proposal Review Panels**

| Instrumentation | Imaging/ Microbeam | Macromolecular Crystallography | Scattering Applied Materials | Scattering Condensed Matter | Scattering Chem/Biol/Environ | Small Angle Scattering (SAXS) | Spectroscopy (EXAFS) |
|---|---|---|---|---|---|---|---|
| Eric Dufresne, Chair | Chris Jacobsen, Chair | Karl Volz, Chair | Paul Fuoss, Chair | Joel Brock, Chair | Neil Sturchio, Chair | Larry Lurio, Chair | Joe Woicik, Chair |
| Wilfried Schildkamp<br>Sarvjit Shastri | Barry Lai<br>John Miao<br>Mark Rivers | Craig Ogata<br>Amy Rosenzweig | I. Cev Noyan<br>Carol Thompson<br>Robert A.Winholtz | John Hill<br>Ben Larson<br>Young S. Lee<br>Guoyin Shen<br>Surendra Saxena | David Tiede<br>Angus Wilkinson | Andrew Allen<br>Jyotsana Lal<br>David Londono<br>Pappannan Thiyagarajan | Simon Bare<br>Lisa M. Miller<br>Sue Mini<br>Matt Newville |

Proposal Review Panels

Beamtime Allocation Committees

356 proposals submitted
for winter run 2003-02
~ 2000 shifts allocated
~ 46% success rate




| Technique | Beamline |
|---|---|
| **Absorption/Spectroscopy** | |
| Fluorescence spectroscopy | 13-BM , 13-ID , 18-ID |
| Intensity fluctuation spectroscopy | 12-ID , 7-ID |
| Photoemission spectroscopy (XPS) | 12-ID , 4-ID-C |
| X-ray absorption fine structure (XAFS) | 10-ID , 11-ID-D , 12-BM , 13-ID , 18-ID , 20-ID , 5-BM-D , 9-ID |
| X-ray magnetic circular dichroism (XMCD) | 11-ID-D , 4-ID-C , 4-ID-D |
| **Imaging** | |
| EXAFS Microscopy | 10-ID , 20-ID |
| Micro fluorescence | 2-ID-B , 2-ID-D , 20-ID |
| Microprobe | 13-BM , 13-ID , 2-ID-D , 20-ID , 7-ID |
| Phase contrast imaging | 1-ID |
| Photoemission electron microscopy (PEEM) | 4-ID-C |
| Radiography | 1-BM |
| Tomography | 13-BM , 2-BM , 5-BM-C |
| **PROTEIN CRYSTALLOGRAPHY** | |
| Macromolecular crystallography | 14-BM-C , 14-BM-D , 14-ID , 17-ID , 19-BM , 19-ID , 5-ID |
| Multi wavelength anomalous dispersion (MAD) | 14-BM-C , 14-BM-D , 14-ID , 17-ID , 19-BM , 19-ID |

# Continuing performance improvements

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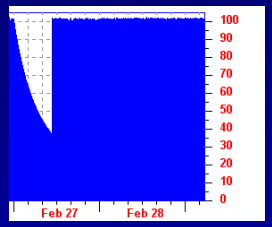
- Top-up operation

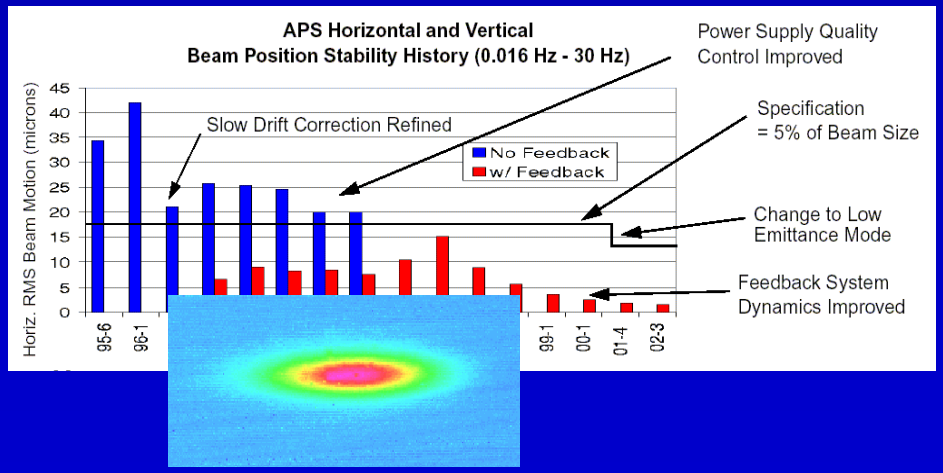
mA



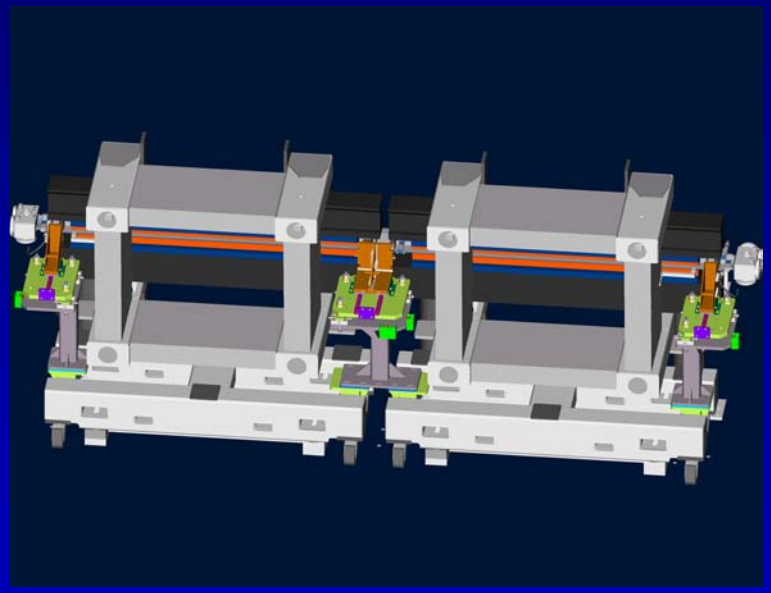

*–Low emittance*

*–Stable optics*

- Improved beam stability




Canted Undulators



while maintaining and improving reliability over 98% ..

# Partnerships for the future…

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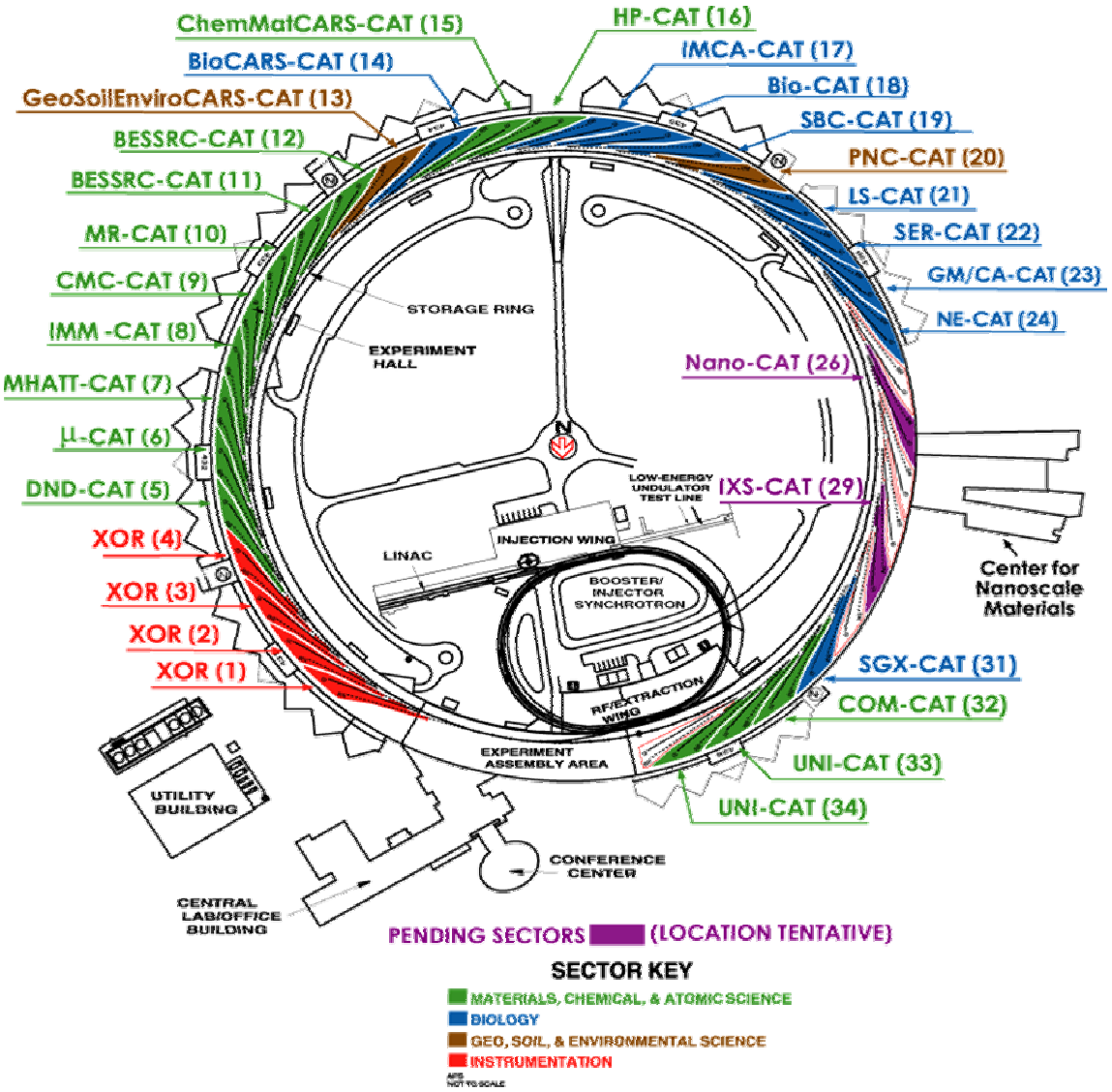

# Imaging nanostructures..

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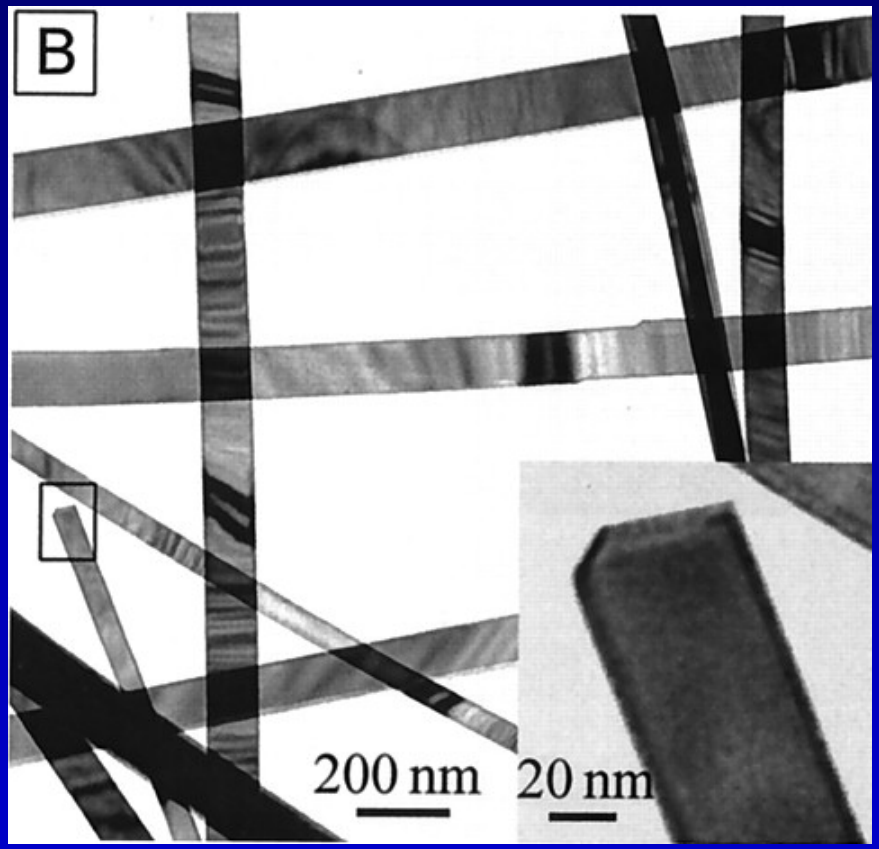


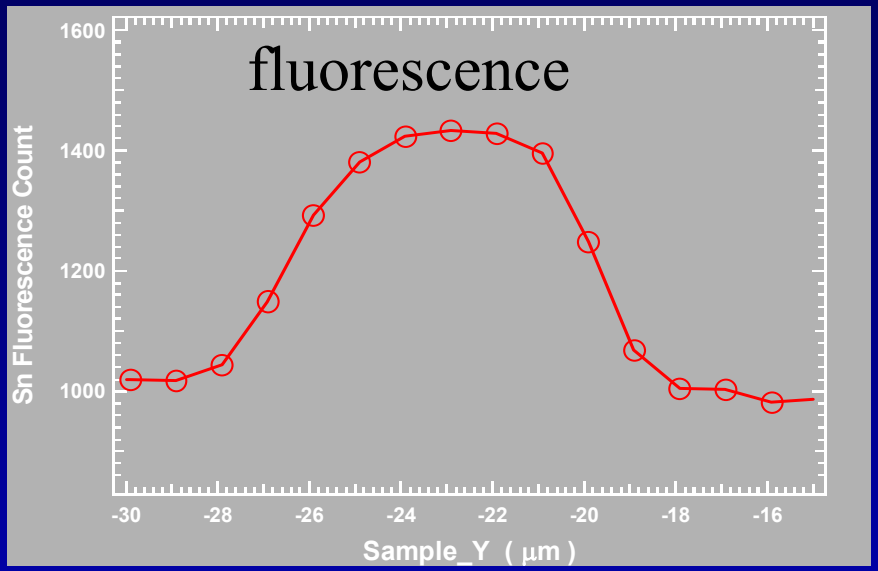


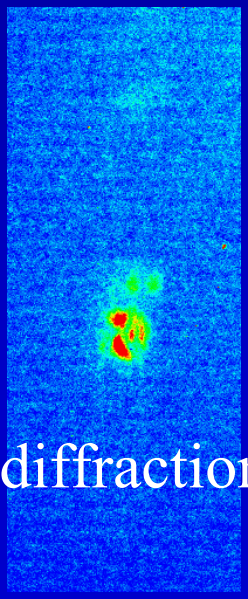

diffraction

**$Sn_2O_3$ nanobelts – Z. Cai**

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Chicago Tribune

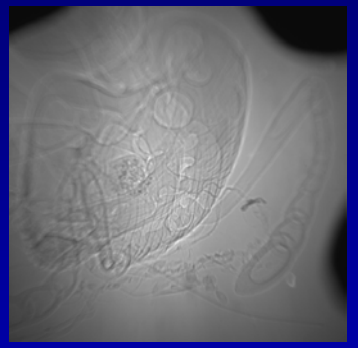
WEST FINAL

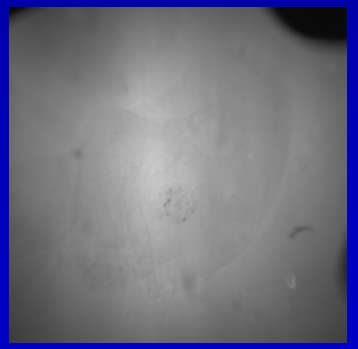
156TH YEAR — NO. 24 © CHICAGO TRIBUNE

FRIDAY, JANUARY 24, 2003

50¢

Argonne video turns ant into a science celebrity





Phase-enhanced imaging

*Westneat, Lee et. al..*

# Center for Nanoscale Materials

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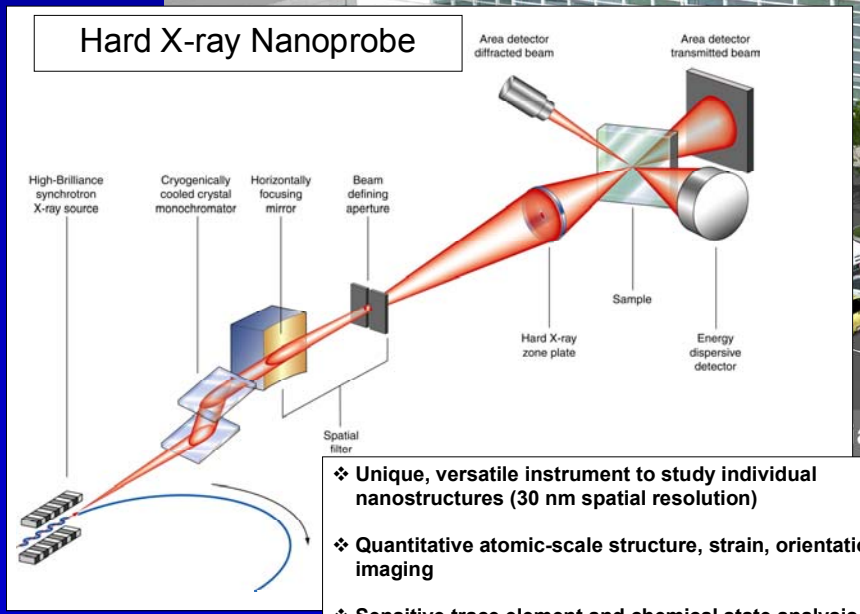
State Contribution FY'02 = $2M, FY'03 = $17M
Building construction begins Summer '03
DOE approves CD-0, anticipated funding $30-40M




- Unique, versatile instrument to study individual nanostructures (30 nm spatial resolution)
- Quantitative atomic-scale structure, strain, orientation imaging
- Sensitive trace element and chemical state analysis
- Ability to penetrate overlayers, environments, fields

User facility for Nanosciences and Nanotechnology
http://nano.anl.gov/

# Free-Electron Lasers – *the excitement of fs science*

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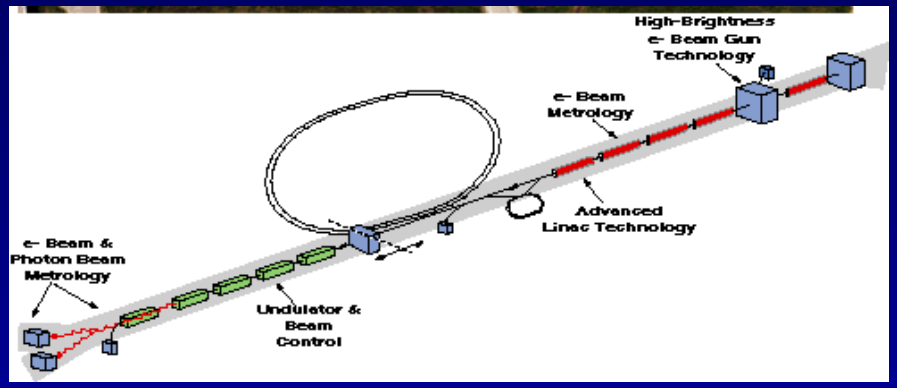
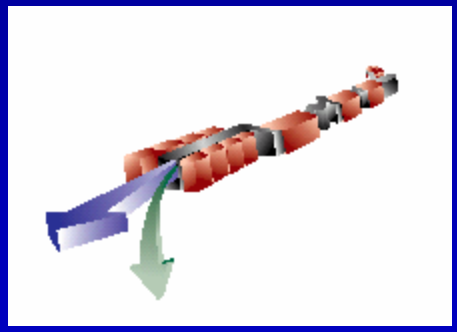
- LEUTL has SPIRIT
  - Experiments ongoing to use single photon ionization from LEUTL source for materials science
  - Proposal submission to BES for upgraded, independent facility (decision point FY '04)




- LCLS

15 GeV Electrons — LCLS — 1.5 Å X-Ray

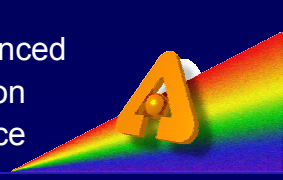
Linac Coherent Light Source



APS to provide undulators at ~$50M responsibility
Steve Milton is the ANL LCLS Project Director

# Current Activities





- Taking more responsibility for BES sector operations
  - 1,2,3,4,11,12, partial 7,8,20…
  - X-Ray Operations and Research replaces SRI CAT
    - Offer 80% time for competition on sectors, >50% GU
  - Encourage specialization
- Developing flexible partnerships
  - Partner and General Users
- New Science Advisory Committee for APS
- Shenoy-Sinha panel on future new science directions for the APS
  - Help determine direction of new beamlines
- Providing enhanced user support
  - Detector pool, beamline controls, ES&H, engineering..

# Budget and staffing

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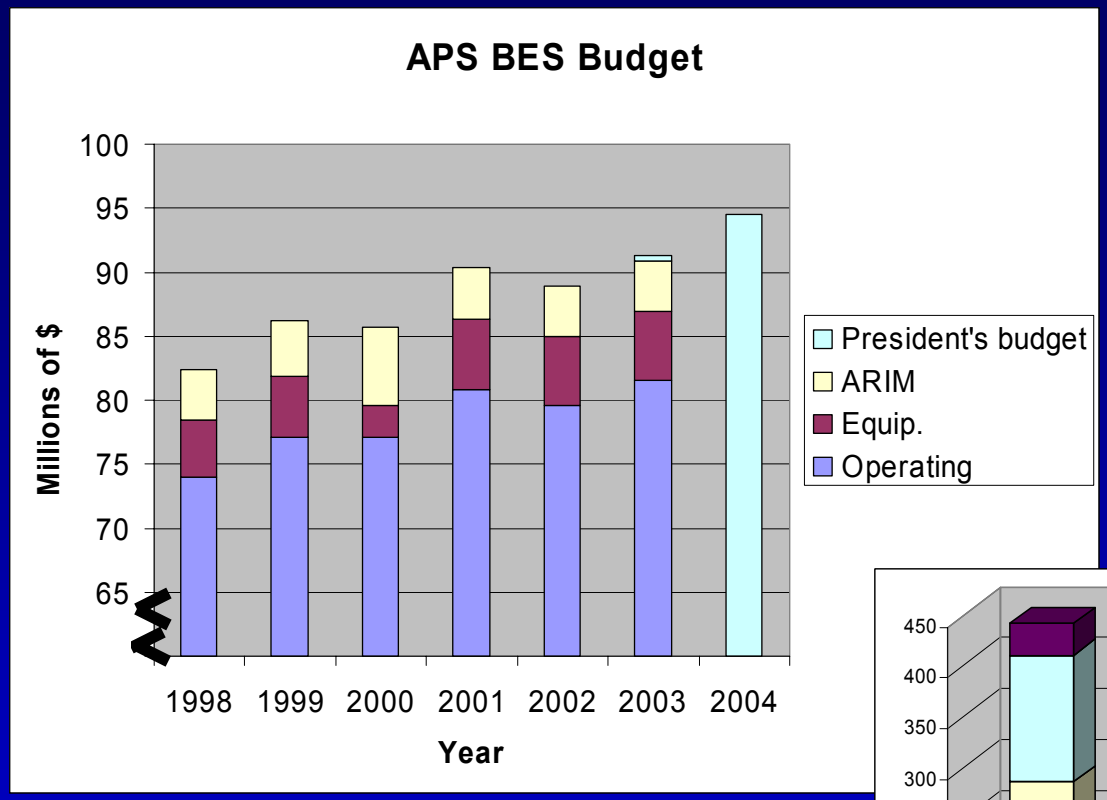


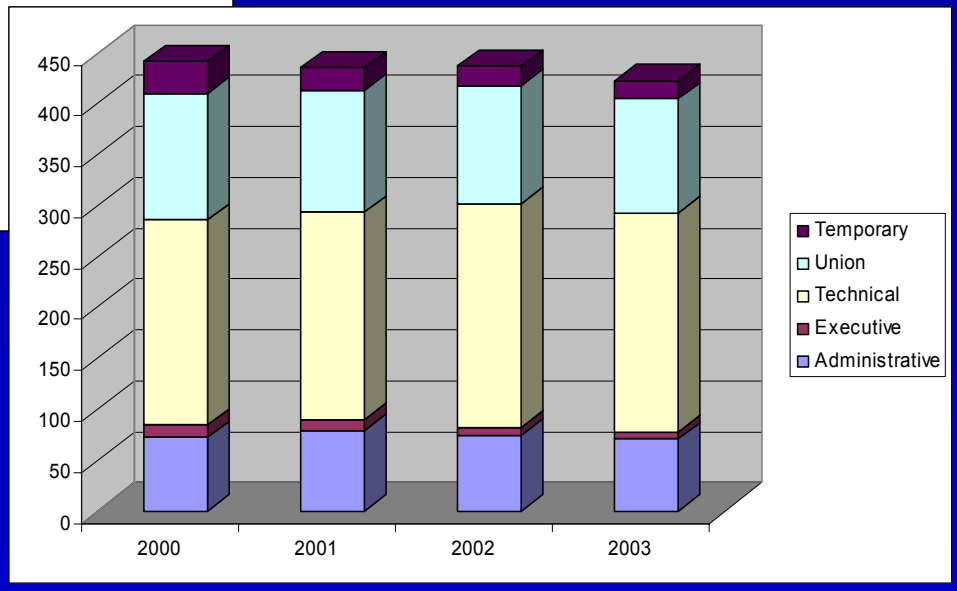

# Increased emphasis on user support

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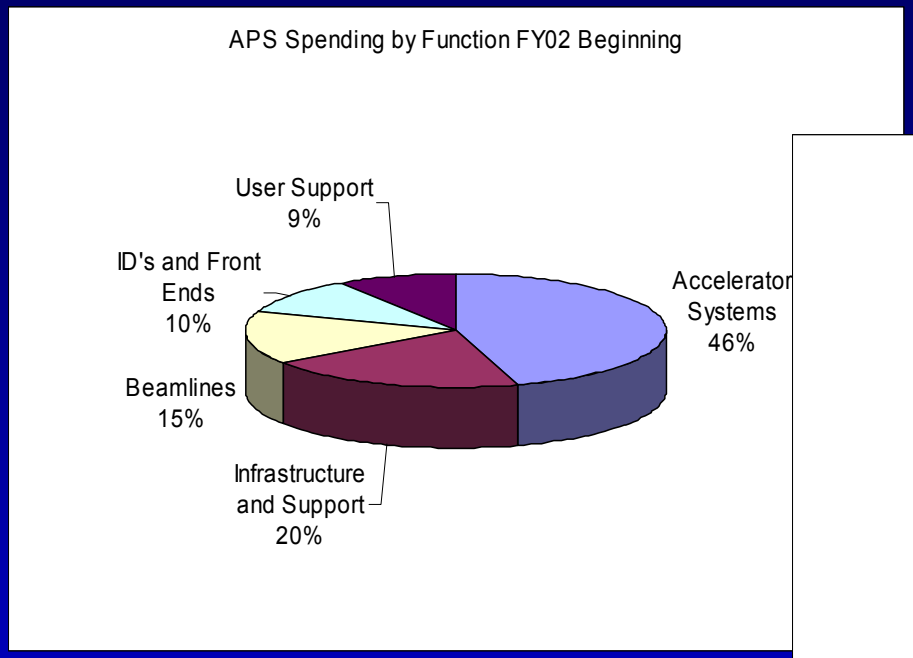


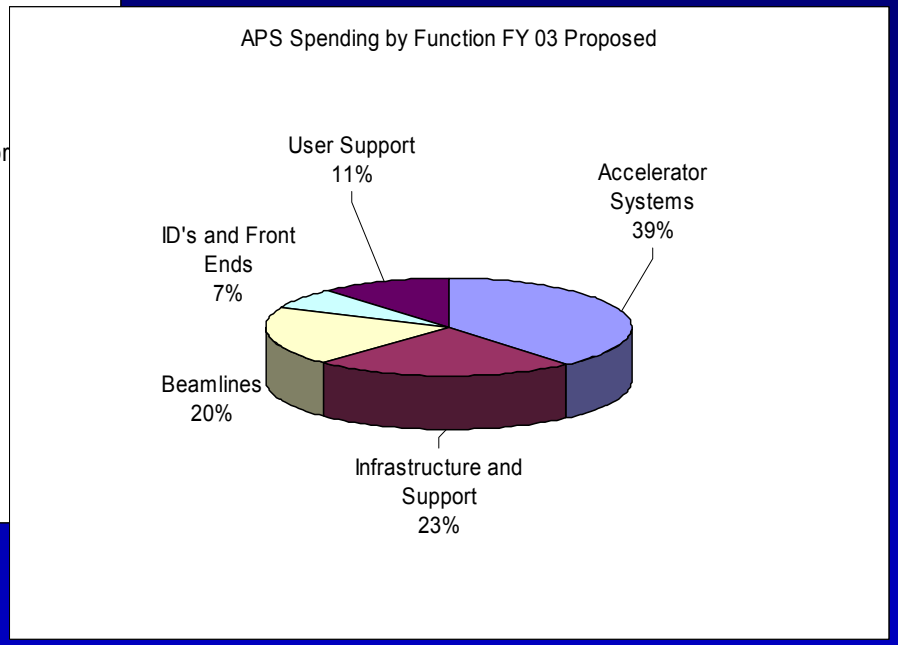


Moved ~7% of resources towards user activities in 2002

Expect future growth in staff and budget for user support

other activities need to remain stable and well-supported


# Advanced Photon Source Upgrade Path

## *Defining the State-of-the-Art*

**Presented to BESAC Subcommittee on 20-year Facilities Roadmap**

**February 23, 2003**

**By J. Murray Gibson**

# State-of-the-Art 3rd Generation Science in 20 Years?

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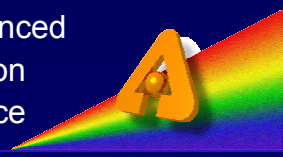

- *Individual* nanoscale objects can be observed in *real-time*
- Electronic, dynamic and magnetic properties of a *single nanostructure* can be measured
- *A few atoms* can be chemically identified
- A full dataset for protein structure analysis can be collected in *less than a second*
- X-ray imaging of objects with *nm resolution* is routine

# Guiding principles for next 20 years

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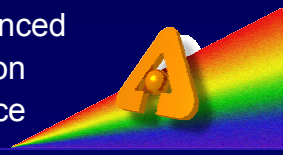

- The mission of the Advanced Photon Source is to deliver world-class science and technology by operating an outstanding synchrotron radiation research facility accessible to a broad spectrum of researchers
- Need for 3rd Generation Sources will not go away in 20 years, and our user base will grow to ~10,000
  - 4th generation is revolutionary, but does not supercede 3rd generation
- Our users and staff should be connected with the next generation capabilities
  - short pulses (fs), higher coherence.
- APS capabilities must increase continually
  - over 1000 times improvement in "useable" brilliance possible within 20 years
- Maintain strong partnerships (such as CATs), and open access for general users

*Defining the state-of-the-art in 3rd generation x-ray sources and science*

# APS phases of innovation in the next 20 years

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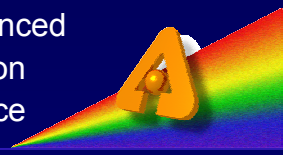

- Phase I – Maximizing Beamline Operations
- Phase II – Maximizing Source Capabilities
- Phase III – Next Generation Facility
- Phase IV – Super Storage Ring

  – Phases II, III and IV each represent at least an order of magnitude increased useable brilliance

# APS Upgrades Timeline

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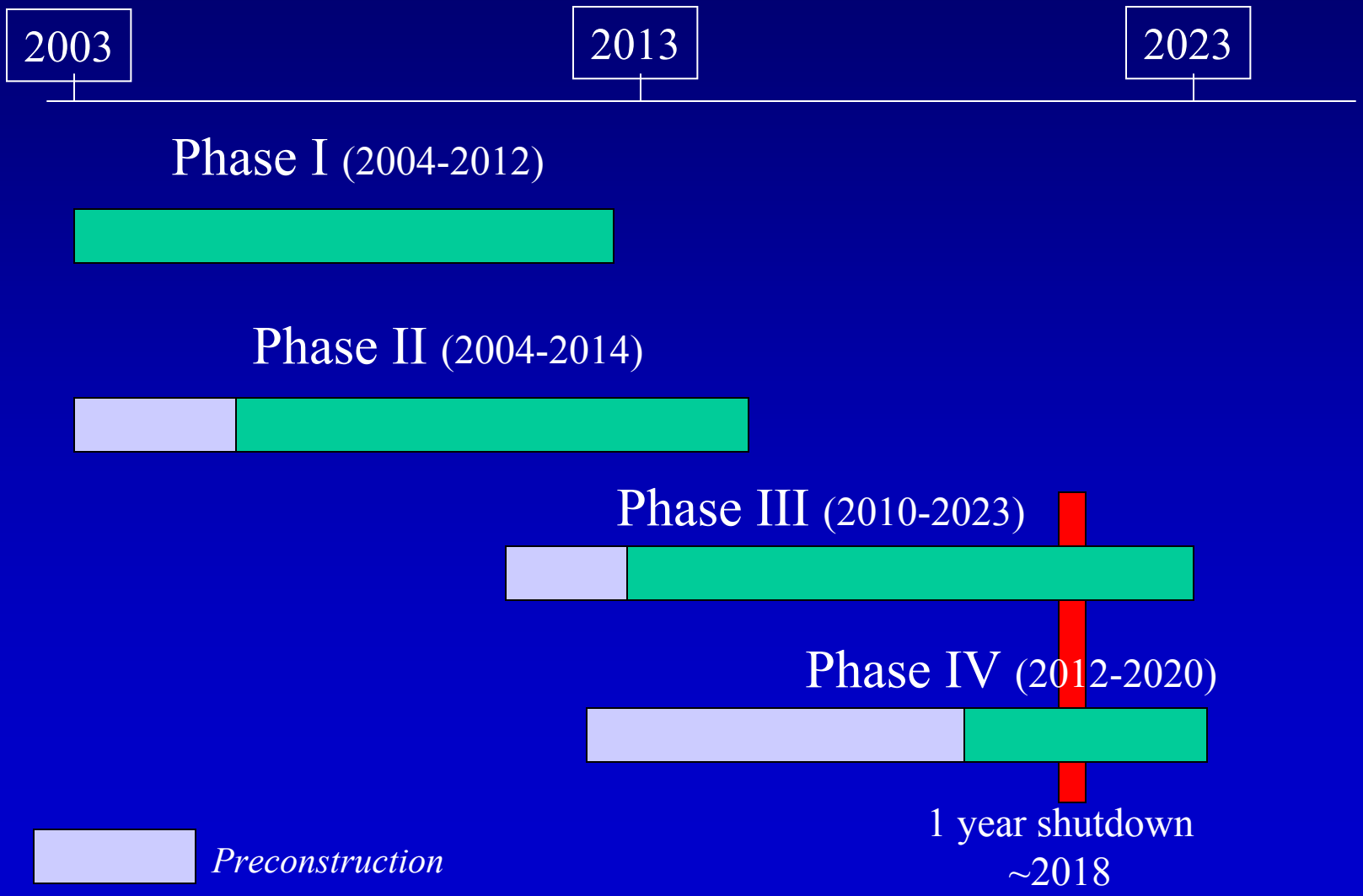

# Phase I – Maximizing Beamline Operations (2004-2012)

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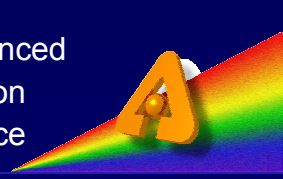

- 10 beamlines to be constructed in the next 8 years (5 years per beamline)
  - more than 1 beamline possible per beamport
- 10 beamlines to be upgraded
  - most likely BES sectors (~26 beamports)
- Construction
  - APS and partner user responsibility
- Operation
  - APS responsibility

# Two kinds of beamlines:

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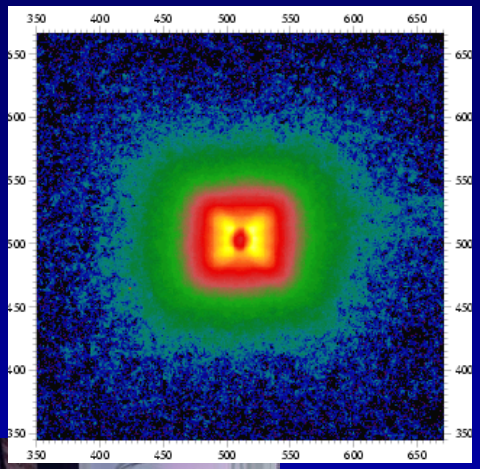
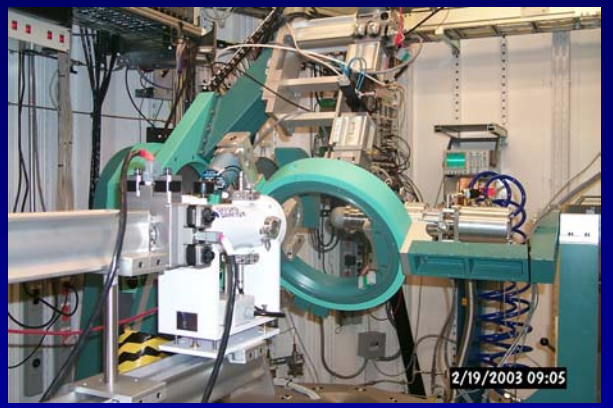
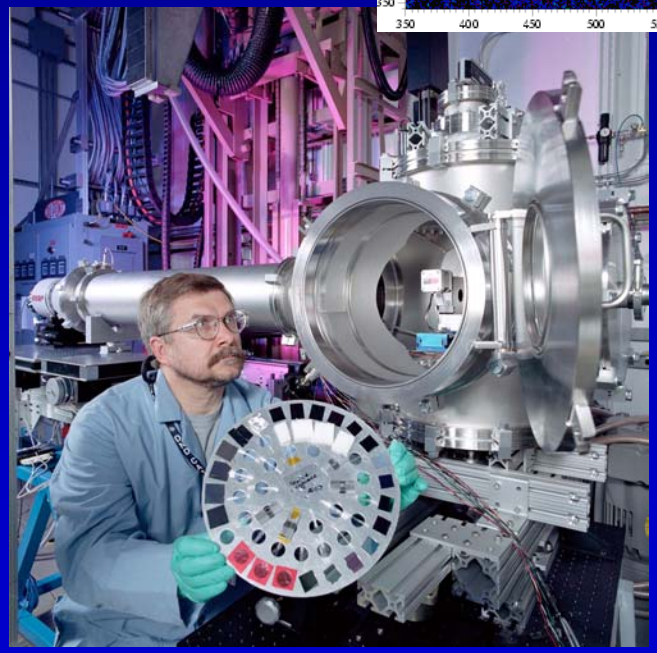
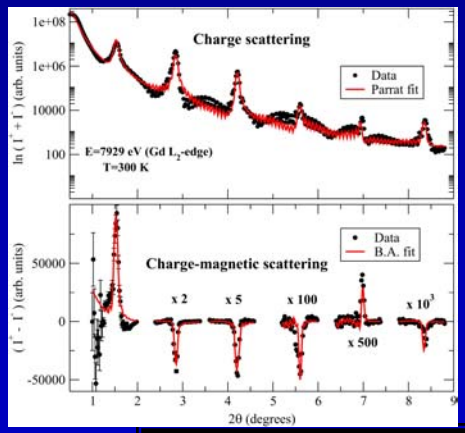
*a "turnkey" beamline to efficiently collect - SAXS*

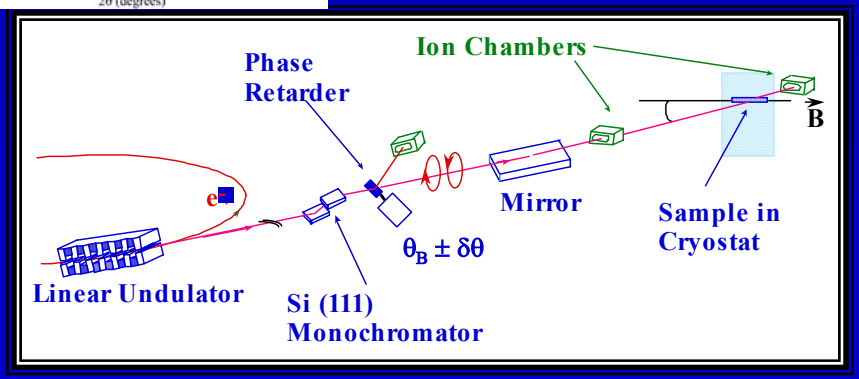





*a dedicated beamline to "do experiments" - magnetic scattering*



# Beamline operation support leverages science

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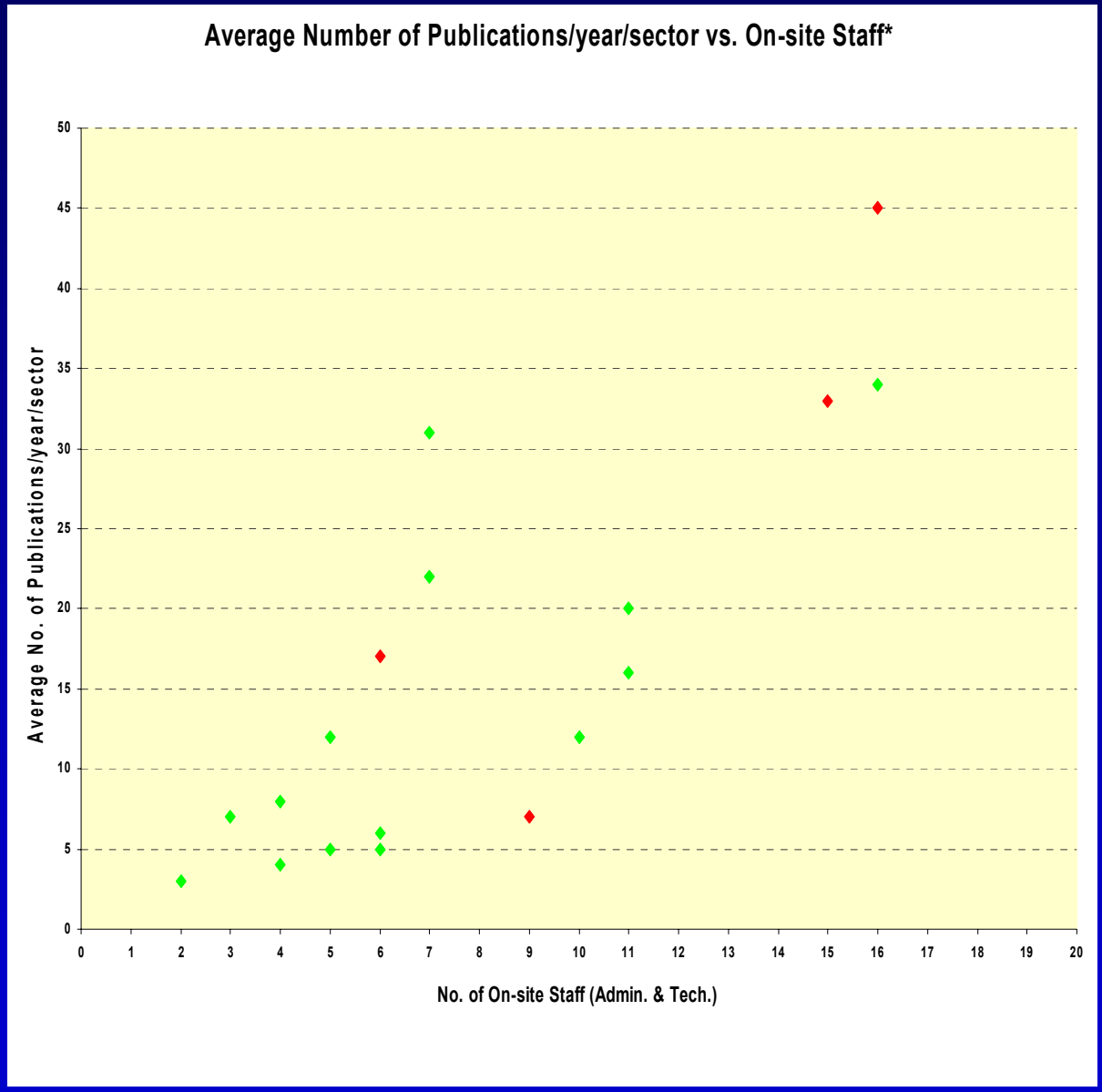

# Phase II – Maximizing Source Capabilities (2004-2014)

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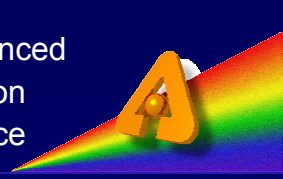
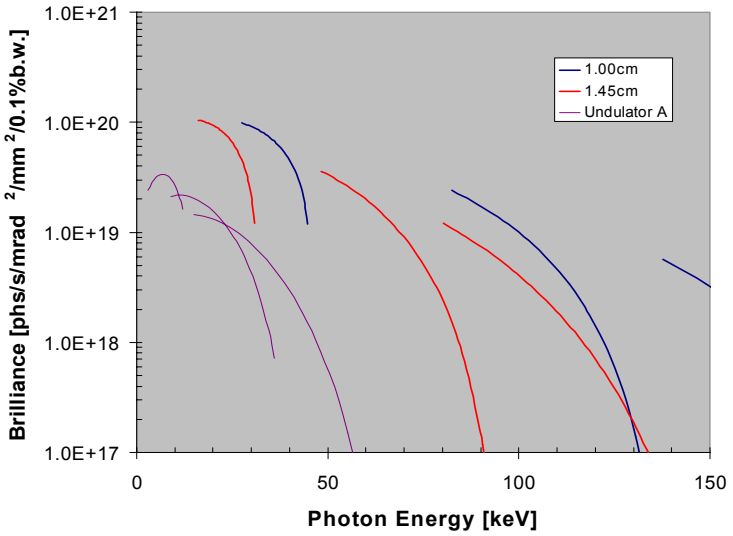


- Innovative undulators, front ends and related components
- Higher brilliance, optimized for application
- Improve front ends and high-heat load optics for higher current operation
  - APS operates at 100mA, would reach 300mA at end of Phase II
- Increasing brilliance by more than an order of magnitude
- Continuing accelerator improvement
  - even greater improvement beam stability

# R&D On Insertion Devices

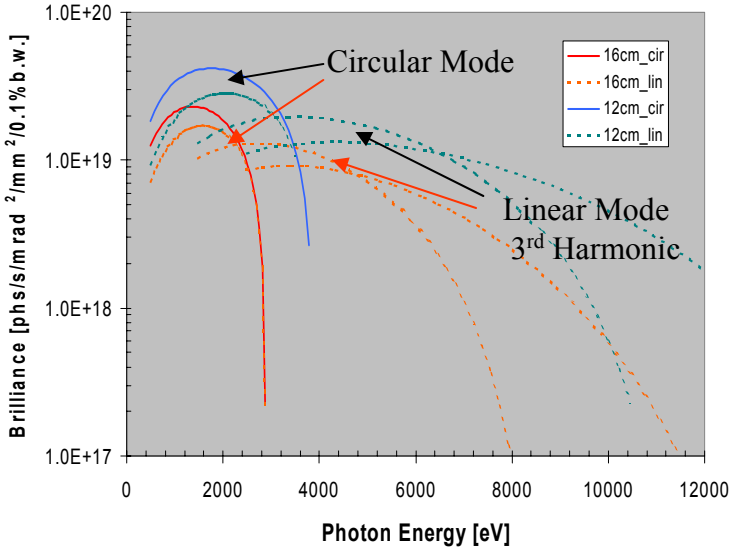



## Superconducting Small Period Undulator

1.45 cm period
L=2.4 m, N=165
Gap=7 mm
Maximum K = 1.4

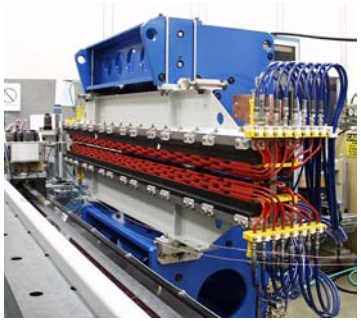
1.00 cm period
L=2.4 m, N=240
Gap = 3 mm
Maximum K = 1.17

## Variable Polarization Undulator



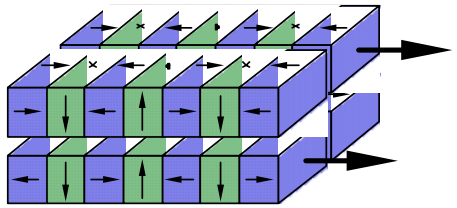

**Electro-magnetic Device**

λ=16 cm, L=10 m, N=62



**APPLE type PM Device**

λ=12 cm, L=10 m, N=82



Assumed APS storage ring parameters: 3.5 nm-rad, 1% coupling, 100 mA

# Phase III – Next Generation User Facility (2010-2023) - *rebuild all beamlines with improved optics, detectors, automation*

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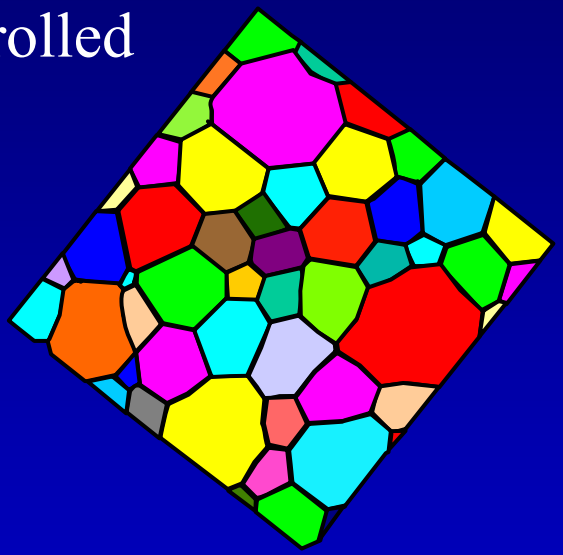
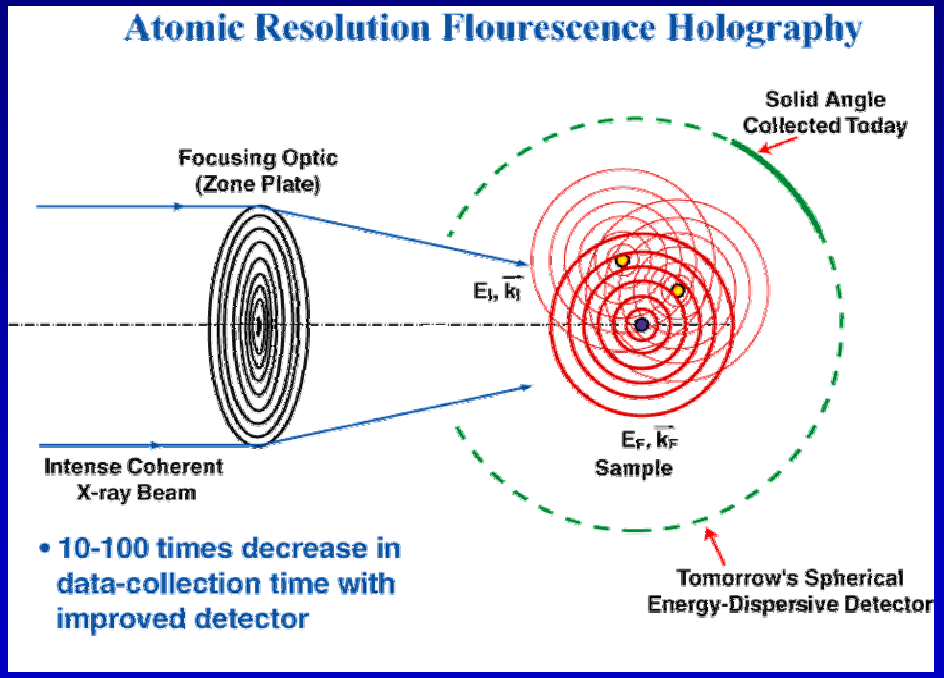
Hot-rolled Al






Map grain orientation and stress in real samples $10^4$ $\mu m^3$ at 1 $\mu m$ resolution
takes 54 hours to collect data
CCD read-out time = 52 hours

# Automation leads to new science

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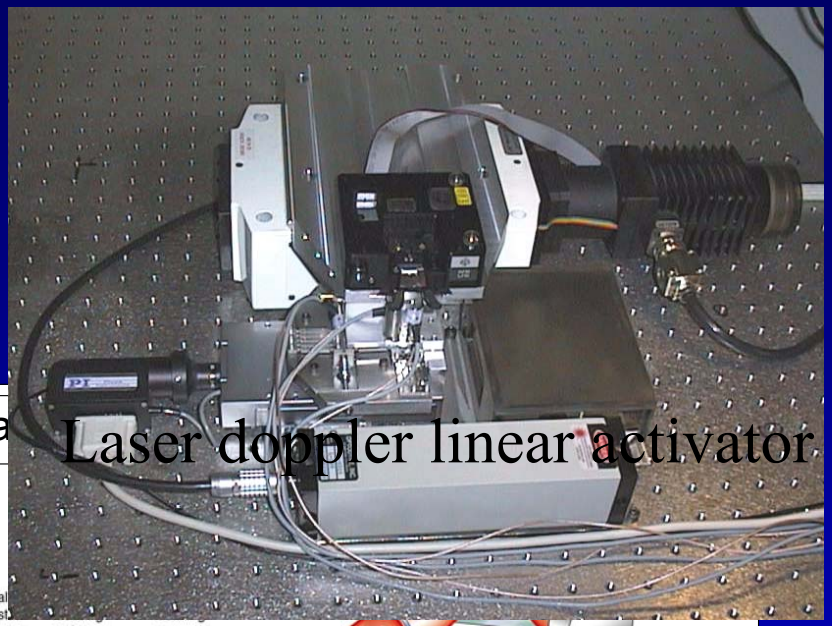
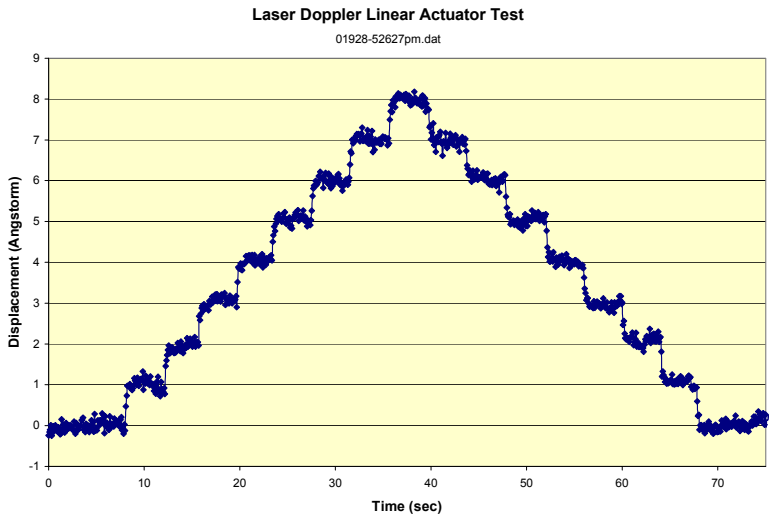
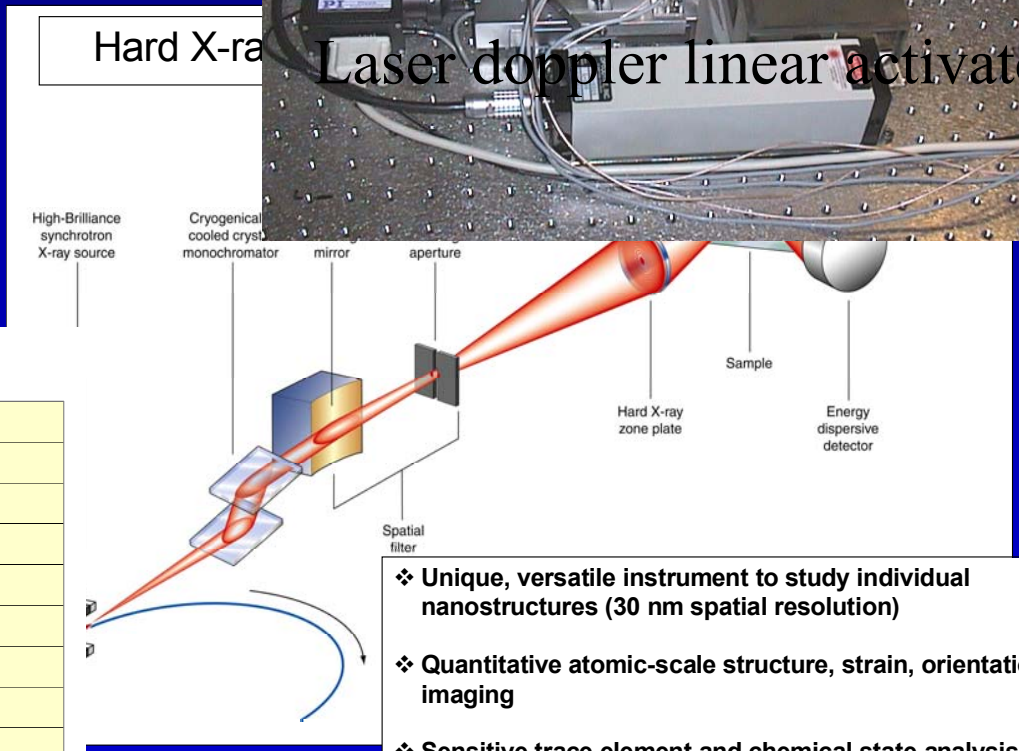
- Not just remote access and user support
- Precision and control exceeds human capabilities
  - Nanoprobe - Scan real and reciprocal space in nanovolumes
  - Adaptive optics with feedback
  - Multi-parameter "smart" scans



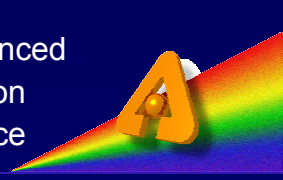




- ❖ **Unique, versatile instrument to study individual nanostructures (30 nm spatial resolution)**
- ❖ **Quantitative atomic-scale structure, strain, orientation imaging**
- ❖ **Sensitive trace element and chemical state analysis**
- ❖ **Ability to penetrate overlayers, environments, fields**

# Phase IV – Super Storage Ring (2012-2020)

Advanced Photon Source

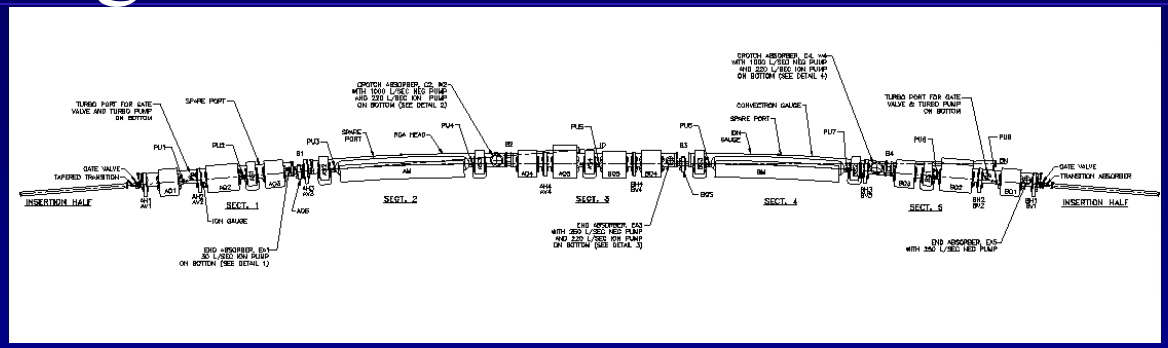


- To upgrade user capabilities and maximize value of embedded infrastructure and community
- Reduce emittance by at least a factor of 10
  - Less than 0.3 nm-rad effective emittance
  - Very short lifetime
    - Requires refined top-up and new injector
- Beam stabilization at 10nm level
- Requires new storage ring and injector
  - New injector offers 4th generation capabilities

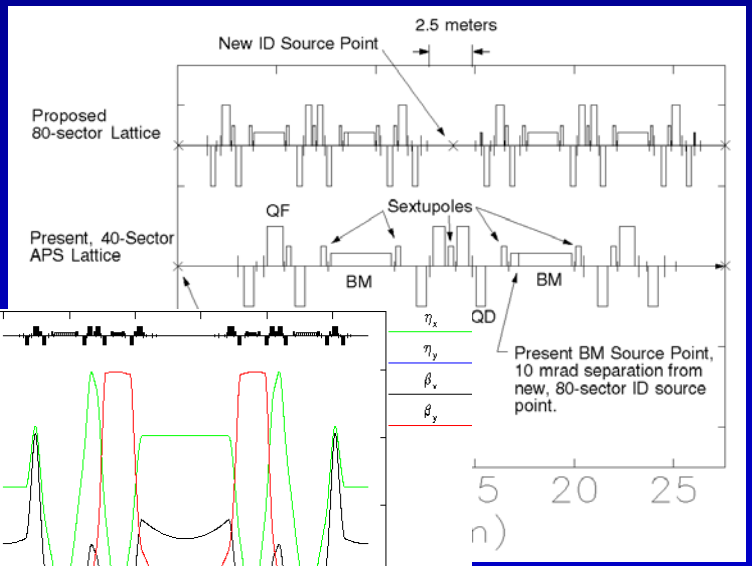
*Preconcept stage– not yet designed*

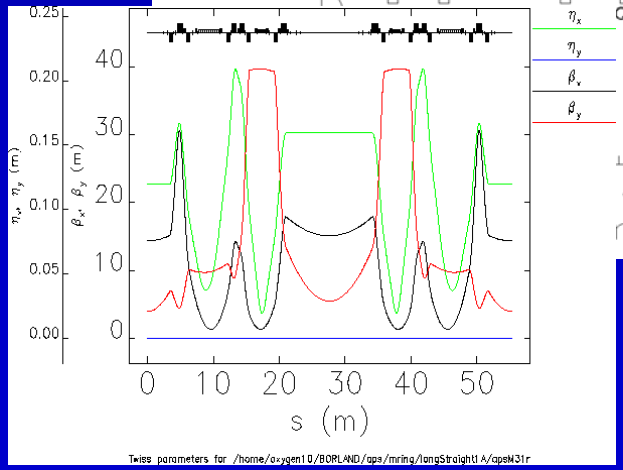
# Super Ring - 80 Sector Lattice

Advanced Photon Source




- **Flexible lattice, uses existing enclosures**
- **use existing BM ports**
- either
  - two short insertion devices (3 - 4 meters) / double sector
- or
  - one long insertion device (up to 12 meters)
  - plus one hard bending magnet source



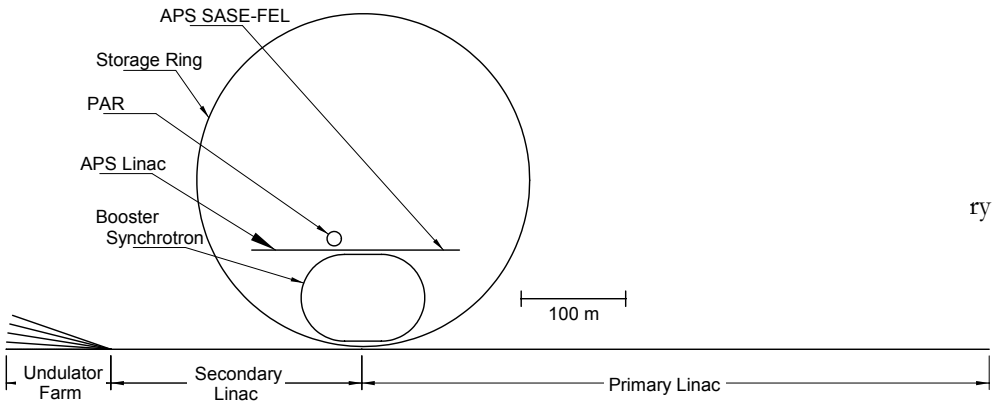
# LINAC Augmented Light Source

Advanced Photon Source

- Fast injection, low emittance *new injector needed…*
- Offers 4th gen.
  - plus new use of existing injectors (UV, IR)

| PARAMETER | VALUE | UNITS |
|---|---|---|
| General | | |
| Total length | 600 | m |
| Cryomodules | 34 | |
| Energy gain per module | 240 | MeV |
| Total beam energy | 8.16 | GeV |
| Average gradient | 13.6 | MV/m |
| RF system | | |
| Operational frequency | 1.3 | GHz |
| Average beam power | 800 | kW |
| Beam | | |
| Charge per bunch | 1 | nC |
| Bunches per macropulse | 1 | |
| Normalized RMS emittance | 14 | μm |
| RMS bunch length | | |
| At injector | 10 | ps |
| At exit of linac | < 1 | ps |
| Macropulse repetition rate | 100 | Hz |

ry Linac parameters



# Conclusion

Advanced Photon Source

- APS today
  - Users, Beamlines, Machine
- Current Activities
  - More responsibility for beamline operation
  - Retain partnerships
  - Evolve more specialized beamlines
  - Provide more user support
- 20-year Plan for the APS
  - Phased upgrade plan offers ~4 orders of magnitude performance improvement
  - Phases I and II strongly endorsed by DOE-BES
- Close interactions between sources should be fostered